BRAC UNIVERSITY

Department of Electrical and Electronics Engineering

THESIS PAPER

BUILDING AN ELECTROMECHANICAL ROBOTIC STRUCTURE OF WALL-E

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DATE: 20 AUGUST, 2015

DECLARATION

This is to declare that the thesis entitled "BUILDING AN ELECTOMECHANICAL ROBOTIC STRUCTURE OF WALL-E" is submitted by our group members in partial fulfillment of the requirements for the award of Bachelor of Science in Electrical and Electronics Engineering during Summer semester in 2015 at BRAC University under the guidance and supervision of DR.MD.KHALILUR RHAMAN. This is our original work and was not submitted elsewhere for the award of any other degree or any other publication.

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ACKNOWLEDGEMENT

We would like to express our gratitude to our supervisor, DR.MD.KHALILUR RHAMAN for his constant and generous advice, valuable contribution, cordial support, motivation and patience. Besides, his guidance has helped us throughout the thesis work to make it fulfilling.

Moreover, we are grateful to MD. MONIR HASAN for his help with the hardware implementation to accomplish our thesis.

Throughout the project we were very supportive, cooperative to each other. Our combined efforts are reflected in this thesis paper.

ABSTRACT

This project presents in detail an electrically operated mechanical robotic system based on an animated character of Pixar's WALL-E (2008). The replica's boxy physical structure is built using plywood mounted on top of track wheel which is a complex mechanical combination of parts like teethed wheel, metallic frames and some soft PVC wood casted shapes driven by 2 independent single shaft geared DC motor. The movements of the arms and neck are attained with the help of servo-motors. This sophisticated entertainment robot has features like its head pivots realistically; movement of different body parts, and also some supplementary enhancements incorporated such as giving WALL-E some vocal through audio system. The main focus of our work is developing a life-size meticulous Arduino-based entertainment robot entirely from custom-fabricated parts with distinctive features which can be controlled wirelessly, motivated from the animated character and as a constant reminder of how we should deal with our technologies without hampering the regular order of our personal and socio-cultural life, we strived for building a life-size robotic structure of WALL-E to keep our conscience ever functional.

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Chapter-1

Introduction

1.1 INTRODUCTION

For thousands of years we have lived exclusive of technology. Of course it has benefited our society in many ways but it has also been a distraction and a nuisance to us as well. If we were able to communicate without if for so many years, than why are we so dependent on it today? Technology is almost like an addiction for human beings. We humans are constantly buried in our technology and unlike in the past, we depend on it to live. Like the humans in the movie WALL-E, we are controlled and driven by technology. It's like an addiction we just can't seem to quit. What will we do one day when technology fails us or goes against us? The rogue robots rebelled against the humans on the Axiom to help WALL-E and Eve save the plant and Earth (WALL-E 2008). Robots could fail us and we would be able to do nothing about it. Technology is aiding us in becoming helpless in our society and unable to fend for ourselves anymore.

Sometimes we need a little awakening and break from technology to remind us of what is going on in the world around us. If we don't wake up and start realizing how technology is affecting us personally, we will be in big trouble in times to come. Now is the time to act and take responsibility for our actions.

1.2 MOTIVATION

The world robot population has reached around 10 million. A number that tells almost 0.16% of the world population are robots. Though Arts and Entertainment (AnE) Robots are not actively being researched, yet it is still in the stage of beginning. It appears to be technological advancement has not yet been made in AnE Robots since it is still being investigated based on the conventional robot technologies. The primary application areas of AnE Robots are for children and elderly who are in need of assistance in learning and independent living [1]. Therefore our consideration through this project was to build an entertainment robot with some principal features and spread light in this domain of robotics.

1.3 BACKGROUND

Robotics deals with the design, construction, operation, and application of robots, as well as computer systems for their control, sensory feedback, and information processing.

These technologies deal with automated machines that can take the place of humans in dangerous environments or manufacturing processes, or resemble humans in appearance, behavior, and/or cognition. Many of today's robots are inspired by nature contributing to the field of bio-inspired robotics.

The concept of creating machines that can operate autonomously dates back to classical times, but research into the functionality and potential uses of robots did not grow substantially until the 20th century. Throughout history, it has been frequently assumed that robots will one day be able to mimic human behavior and manage tasks in a human-like fashion. Today, robotics is a rapidly growing field, as technological advances continue; researching, designing, and building new robots serve various practical purposes, whether domestically, commercially, or militarily. Many robots do jobs that are hazardous to people such as defusing bombs, mines and exploring shipwrecks [2].

The Entertainment Robot, or E-Robot, is a kind of personal robot which is designed to co-exist with human beings in their everyday lives. This is a relatively new entry to the market compared to the industrial robot, which has a much longer history and has been used mostly in factories for improving the productivity of various industries.

WALL-E: an electromechanical entertainment robot is built from scrap parts and metals to be collected from local sources with the help of some reference materials available on the internet.

1.4 ENTERTAINMENT ROBOT

The E-Robot evolved into various types of personal robot and became an increasingly common and beneficial partner of human beings. Chip technology played a crucial role for the evolution of the personal robot by enhancing its intelligence, sensing performance and motion capability. The E-Robot is a symbolic product which has already established a milestone for the new wave of robotics building in this new century. Today's situation is similar to that of the early 1980's, when the PC was introduced. Not many people foresaw the tremendous impact of the PC in the following decades. Robots will create a similar kind of impact on our society in the coming decades. Figure-1.1 shows projected market trends for robots in Japan by Japan Robot Association. In 2000, the majority of the robotic market was for the manufacturing industry It was expected, however, that personal robots will boost the total market to around 30B$ by 2010, which is bigger than today's PC market in Japan. Then it was predicted that the next few decades, the electronics industry will be driven by robots, with E-Robots playing the leading role, as shown in Figure-1.2 [3]

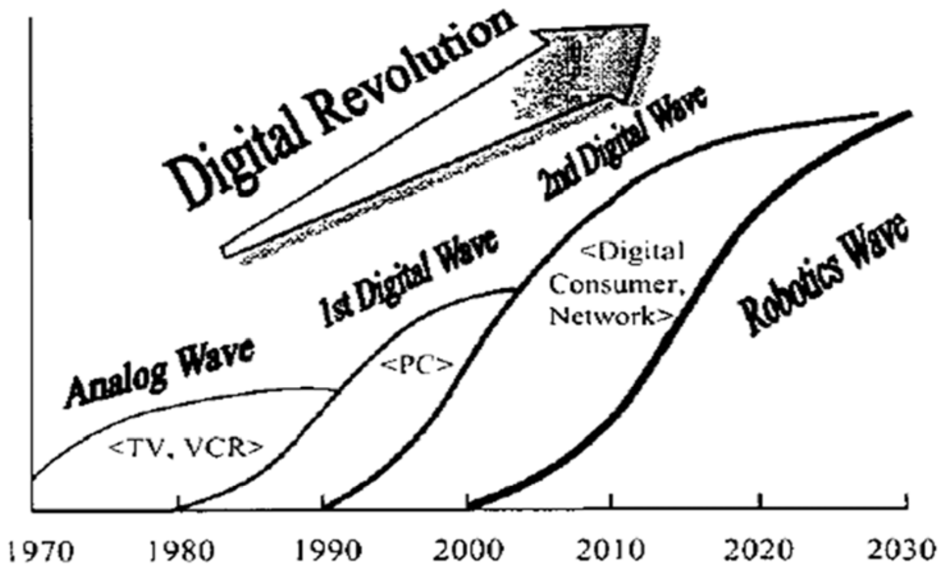

Figure-1.1: The rising new wave of robotics

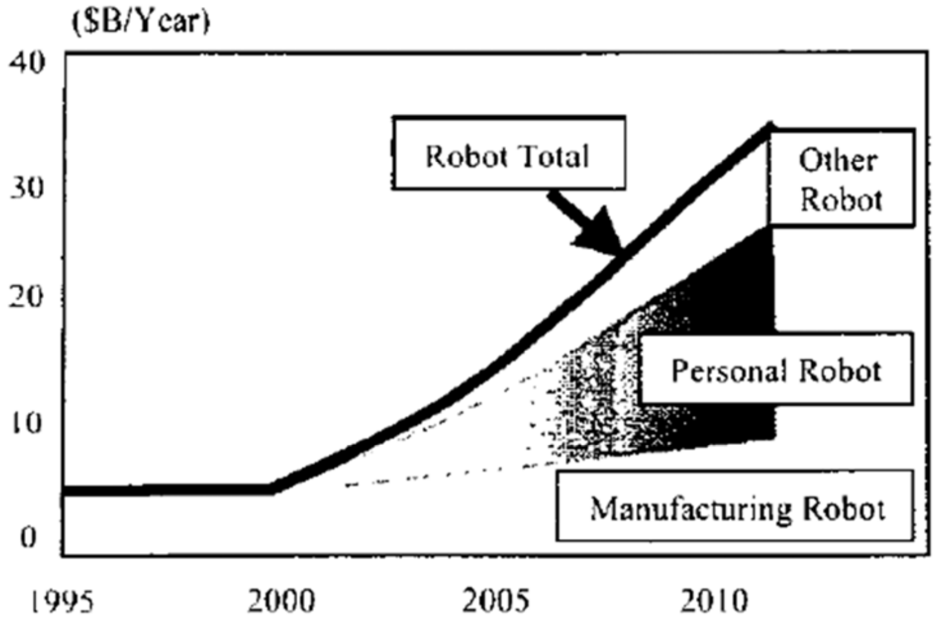

Figure-1.2: Market forecast of robotic industry in Japan

1.4.1 BANGLADESH PERSPECTIVE

Bangladesh is surprisingly on the cutting edge of innovation when it comes to mobile and digital solutions to problems. In our country E-Robot did not yet become so popular, though the budding enthusiasts have explored in the field of robotics. Electromechanical E- Robots have not yet been commercialized in our country and very limited funds are allocated for advancement in this sector of electronics.

1.5 AIM AND SCOPE OF THESIS

Already in ancient time we have learnt to stimulate our feelings by different means of entertainment. In recent years robotic applications in the entertainment industry has advanced. So there are robots used as amusement rides , there are animatronics robots that entertain people at different festivals and amusement parks. And of course - there are robot toys. These form a large part of all entertainment robots.

The main focus of our work is developing a life-size meticulous Arduino-based entertainment robot entirely from custom-fabricated parts with distinctive features which can be controlled wirelessly.

1.6 RELATED WORKS

Motivated by the notions developed around the character WALL-E, there is a handful of works that has been done over the last few years even before the movie came out. There is a WALL-E Builders Group formed in the state of California prior to the release of the movie and they had to start building WALL-E from the scratch were nothing other than some screen grabs, movie posters and imagination. People from different parts of the globe started to join and share what they are up to, their designs and work progress and very soon the group turned full of content for those willing to venture a mesmerizing build of WALL-E. Mike Senna and McMaster are two of the main architects of WALL-E builders club who nailed the first replica of the exact CGI of WALL-E which are near impeccable. All the works that has been done and still being done are being shared on this group and it has been a goldmine for the newly WALL-E enthusiasts turned builders.

Chapter-2
Segment wise design
Of
Structure

The following are the designs attributing for the shapes of modified fragmental anatomy of WALL-E's structure.

2.1 WHEEL

Figure-2.1: Cross section of Wheel

2.2 EYE

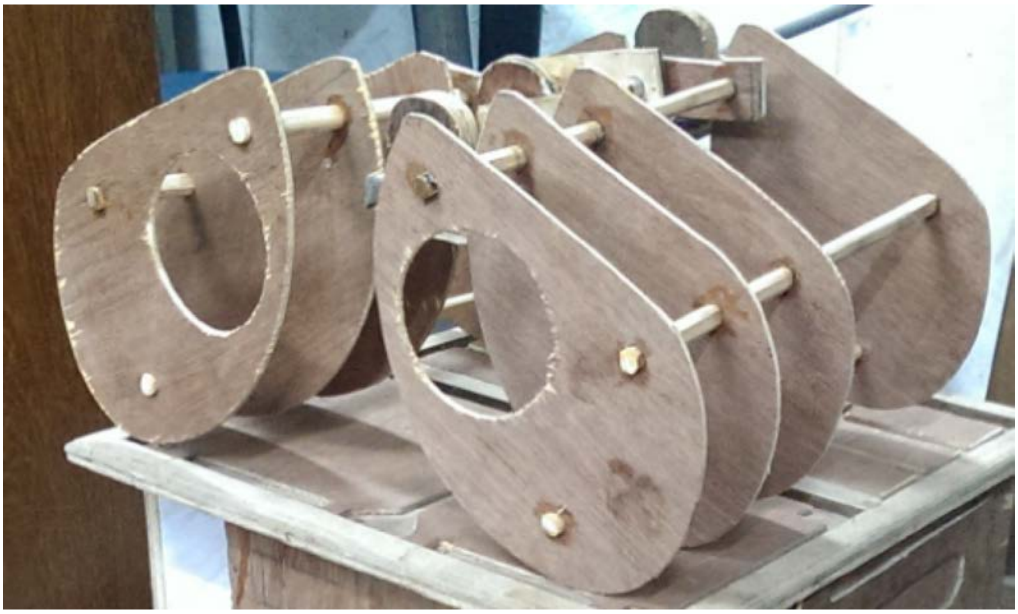

Figure-2.2: Cross-section of Eye

The eyes' appropriate contour was furnished using blue colored concavo-convex lens.

2.3 HAND

Figure-2.3: Cross-section of Hand

2.4 <u>BODY</u>

Figure-2.4: Structure of Body

The body structure was constructed using plywood so we could make a perfect replica of WALL-E and it was also light weight.

2.5 IMPLEMENTED SYSTEM MODELLING

Figure-2.5: Modeling of different parts

Chapter-3
Components Used

3.1 ARDUINO MEGA 2560 R3

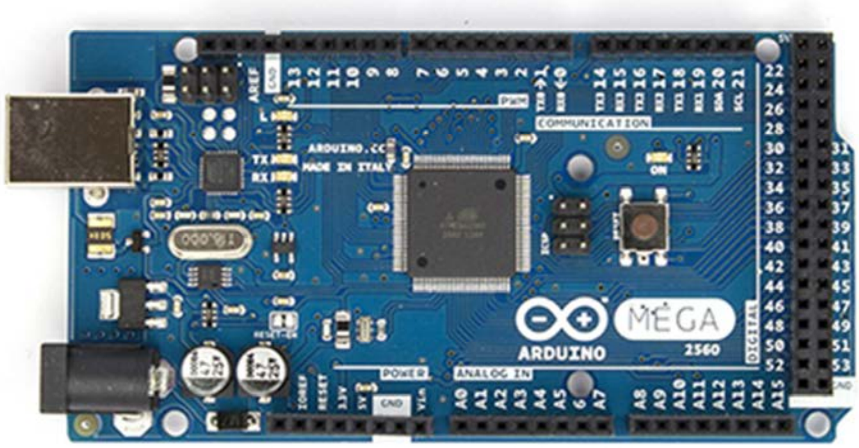

Figure-3.1: Arduino Mega

Arduino is an open-source platform used for constructing and programming of electronics. It can receive and send information to most devices, and even through the internet to command the specific electronic device.

The Arduino Mega 2560 is a microcontroller board based on the ATmega2560 . It has 54 digital input/output pins (of which 15 can be used as PWM outputs), 16 analog inputs, 4 UARTs (hardware serial ports), a 16 MHz crystal oscillator, a USB connection, a power jack, an ICSP header, and a reset button. It contains everything needed to support the microcontroller; simply connecting it to a computer with a USB cable or power it with a AC-to-DC adapter or battery will start it.

Specifications

Microcontroller	ATmega2560
Operating Voltage	5V
Input Voltage (recommended)	7-12V
Input Voltage (limits)	6-20V
Digital I/O Pins	54 (of which 15 provide PWM output)
Analog Input Pins	16
DC Current per I/O Pin	40 mA
DC Current for 3.3V Pin	50 mA
Flash Memory	256 KB of which 8 KB used by bootloader
SRAM	8 KB
EEPROM	4 KB
Clock Speed	16 MHz

The Arduino Mega can be powered via the USB connection or with an external power supply. The power source is selected automatically. [4]

3.2 <u>REMOTE CONTROLLER</u>

Figure-3.2: 2.4 GHz Digital proportional radio control system

Transmitter Parameters

- Channels：6
- Charger port: Yes
- Frequency band: 2.4GHz
- Simulator port: PS-2
- Power resource：1.5V*8 "AA" Battery
- Program type: GFSK
- Modulation type: FM
- RF power：19 db
- Static current：≤250mA
- Voltage display type：LED [5]

3.3 SERTVO MOTOR

Theory of Servo Motors:

This is simple electrical motor, controlled with the help of servomechanism. The position of the servo motor is set by the length of a pulse. The servo expects to receive a pulse roughly every 20 milliseconds. If that pulse is high for 1 millisecond, then the servo angle will be zero, if it is 1.5 milliseconds, then it will be at its center position and if it is 2 milliseconds it will be at the maximum allowable degrees.

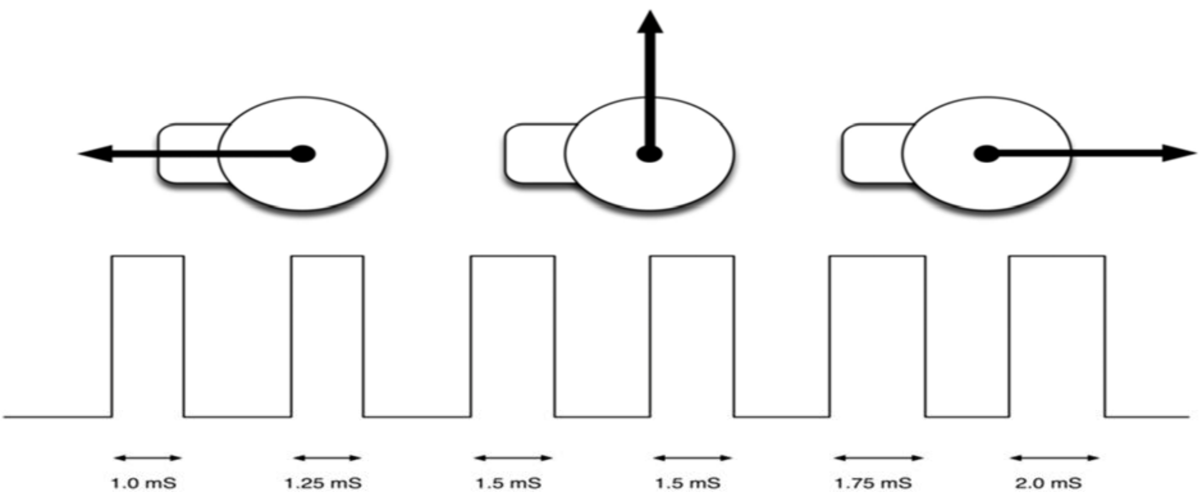

Figure-3.3: Angular position according to width of pulse

The end points of the servo can vary and many servos only turn through about 170 degrees. There are also 'continuous' servos that can rotate through the full 360 degrees**.**

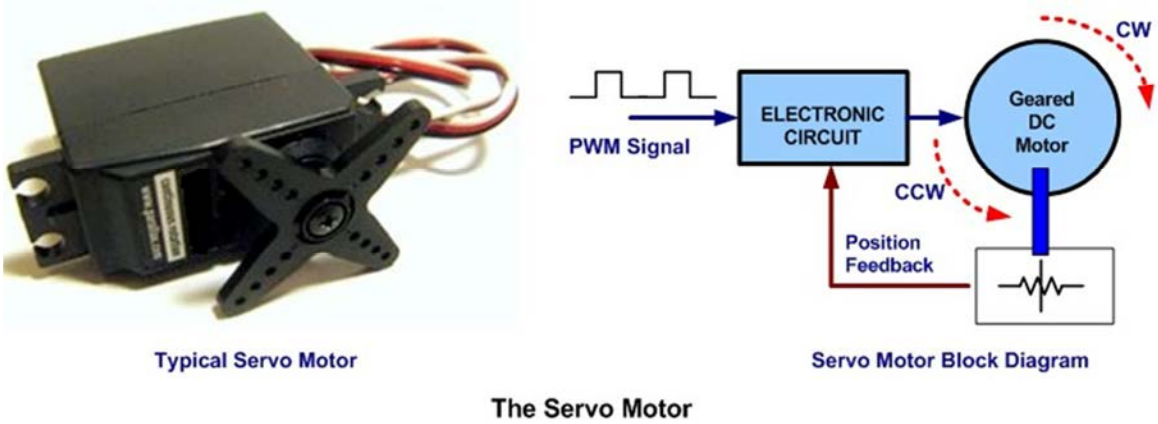

Figure-3.4: Mechanism of Servo Motor

3.3.1 MG995(High Speed Metal Gear Dual Ball Bearing Servo)

Figure-3.5: MG995

This high-speed standard servo can rotate approximately 180 or 360 degrees.

Specifications

- Weight: 55 g
- Dimension: 40.7 x 19.7 x 42.9 mm approx.
- Stall torque: 8.5 kgf·cm (4.8 V), 10 kgf·cm (6 V)
- Operating speed: 0.2 s/60º (4.8 V), 0.16 s/60º (6 V)
- Operating voltage: 4.8 V a 7.2 V
- Stable and shock proof double ball bearing design
- Temperature range: 0 ºC – 55 ºC

[6]

3.3.2 MG996(High Speed Metal Gear Dual Ball Bearing Servo)

Figure-3.6: MG996

Specifications

- Weight: 55 g
- Dimension: 40.7 x 19.7 x 42.9 mm approx.
- Stall torque: 9.4 kgf•cm (4.8 V), 11 kgf•cm (6 V)
- Operating speed: 0.17 s/60º (4.8 V), 0.14 s/60º (6 V)
- Operating voltage: 4.8 V a 7.2 V
- Running Current 500 mA – 900 mA (6V)
- Stall Current 2.5 A (6V)
- Temperature range: 0 ºC – 55 ºC

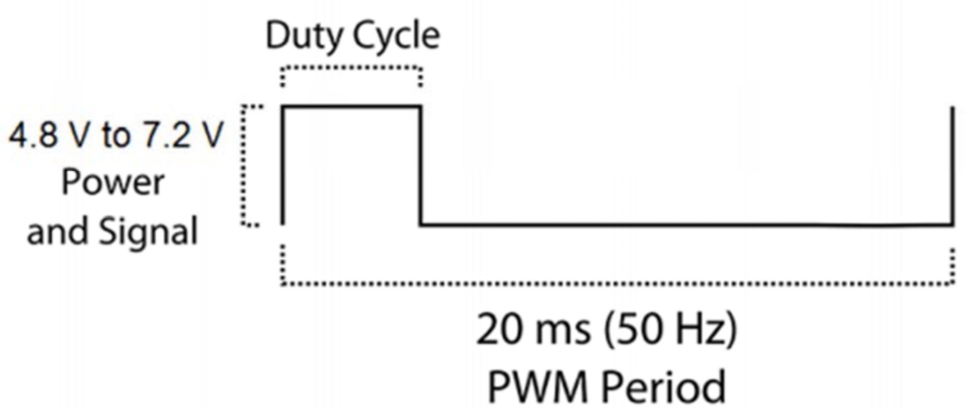

Figure-3.7: Pulse of 50Hz [7]

3.4 GEARED DC MOTORS

Theory of DC MOTORS

Geared DC motors can be defined as an extension of DC motor that has a gear assembly attached to the motor. The speed of motor is counted in terms of rotations of the shaft per minute and is termed as RPM .The gear assembly helps in increasing the torque and reducing the speed. Using the correct combination of gears in a gear motor, its speed can be reduced to any desirable figure. This concept where gears reduce the speed of the vehicle but increase its torque is known as gear reduction. This Insight will explore all the minor and major details that make the gear head and hence the working of geared DC motor.

Let's consider a permanent magnet brushed motor. The piece connected to the ground is called the stator and the piece connected to the output shaft is called the rotor. The inputs of the motor are connected to 2 wires and by applying a voltage across them, the motor turns.

The torque of a motor is generated by a current carrying conductor in a magnetic field. The right hand rule states that if you point your right hand fingers along the direction of current, I, and curl them towards the direction of the magnetic flux, B, the direction of force is along the thumb.

Now, imagine a loop of wire with some resistance is inserted between the two permanent magnets. The following diagrams show how the motor turns:

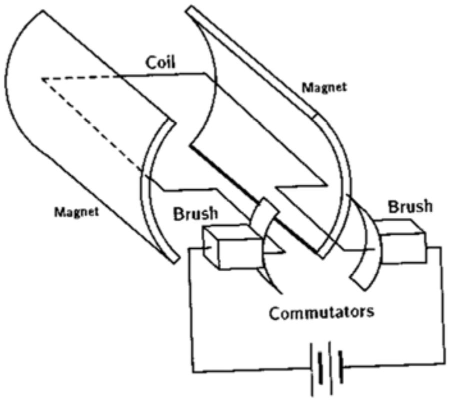

Figure-3.8: Working Principle of DC motor

You might be able to notice that the direction of rotation is changing every half cycle. To keep it rotating in the same direction, we have to switch the current direction. The process of switching current is called commutation. To switch the direction of current, we have to use brushes and commutators.

Commutation can also be done electronically (Brushless motors) and a brushless motor usually has a longer life.

3.4.1 DC Motor Used In our System

Figure-3.9: Single Shaft Geared DC Motor

3.5 Card Reader Shield for Music

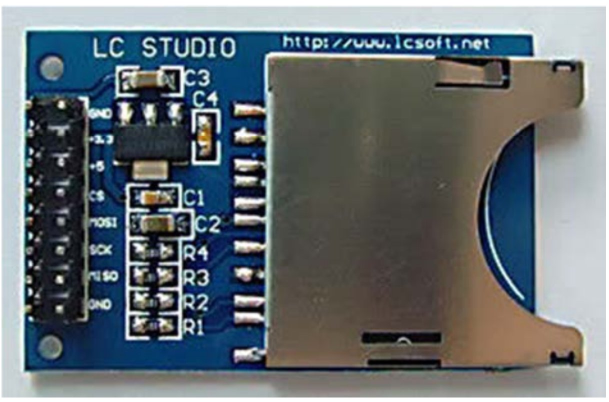

Figure-3.10: Card Reader Shield

3.6 RELAY

Relays are simple switches which are operated both electrically and mechanically. Relays consist of a n electromagnet and also a set of contacts. The switching mechanism is carried out with the help of the electromagnet. There are also other operating principles for its working. But they differ according to their applications. Most of the devices have the application of relays.

Why is a relay used?

The main operation of a relay comes in places where only a low-power signal can be used to control a circuit. It is also used in places where only one signal can be used to control a lot of circuits. The high end applications of relays require high power to be driven by electric motors and so on. Such relays are called contactors.

Relay Design

There are only four main parts in a relay. They are

- Electromagnet
- Movable Armature
- Switch point contacts
- Spring

How relay works?

The working of a relay can be better understood by explaining the following diagram given below.

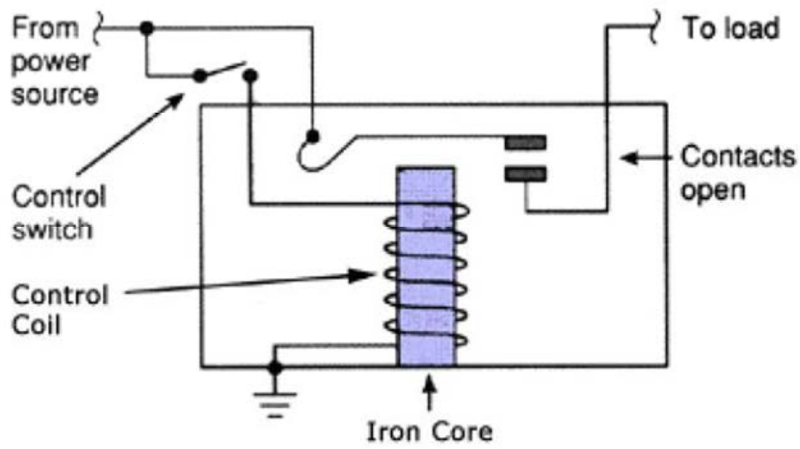

Figure-3.11: Working Principle of a Relay

Relays are mainly made for two basic operations. One is low voltage application and the other is high voltage. For low voltage applications, more preference will be given to reduce the noise of the whole circuit. For high voltage applications, they are mainly designed to reduce a phenomenon called arcing. [9]

3.6.1 Relay Shield in our System

Figure-3.12: 30A relay shield

3.7 POWER BANK

Figure-3.13: Power Bank

3.10 SOLAR CHARGE LEVEL LIGHTING

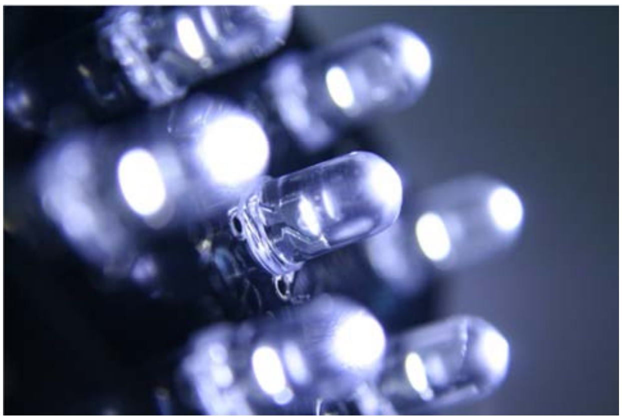

Figure-3.14: LED Charge Light

3.9 12V BATTERY

Figure-3.15: 12V Battery

3.12 SPEAKER

Figure-3.16: Speaker

Chapter-4
System Architecture
&
Implementation
Of the
System

4.1 SYSTEM LAYOUT

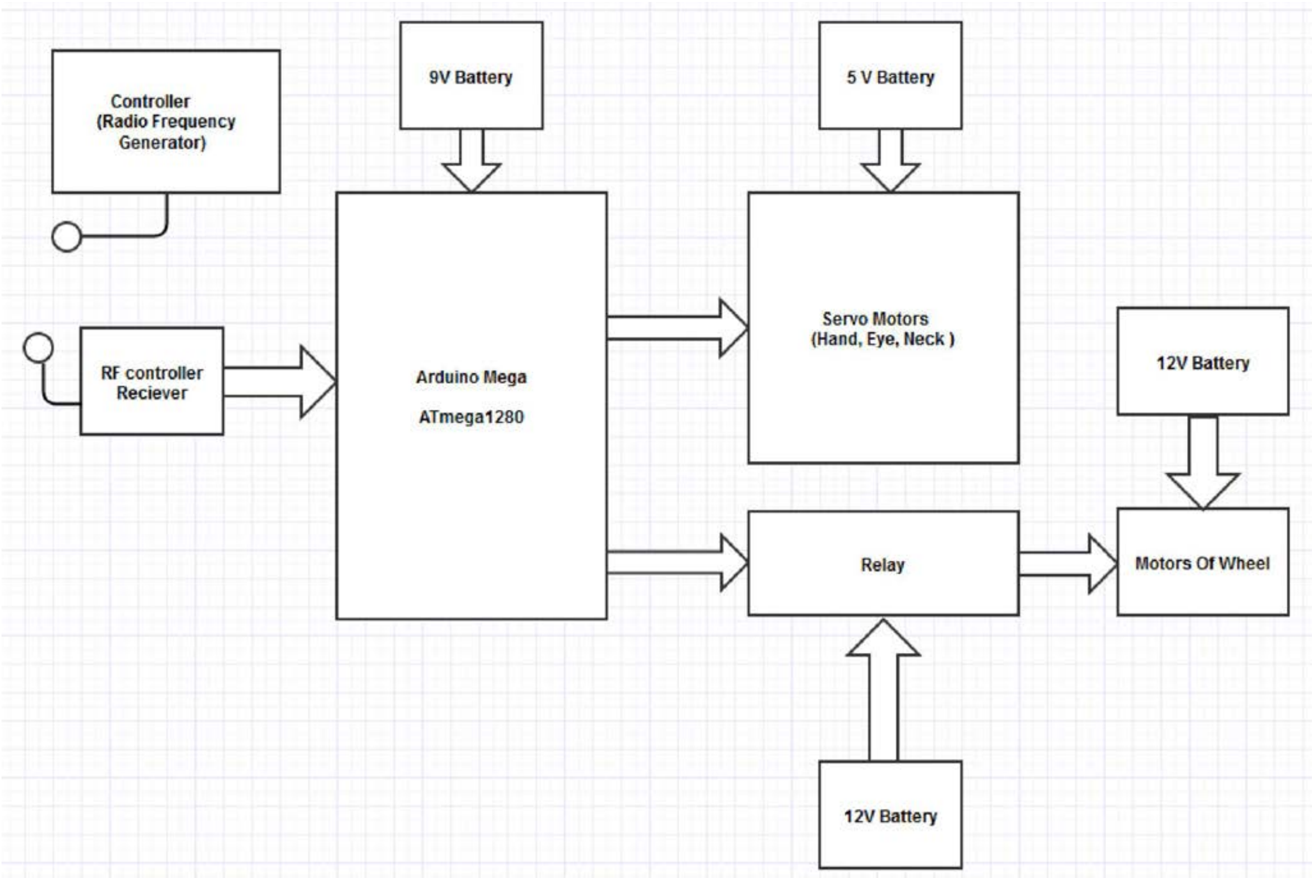

Figure-4.1: Block diagram of WALL-E's mechanism

The block diagram shows receiver receives the signal transmitted from the transmitter and the pulse signal is fed into the arduino through square voltage pulse (0-5V) which is variable. Arduino having a built in function pulseIn() function returns the pulse width in micro second. Then exploit this pulse width to control different movements- neck, eye, hand, forward and backward movement of wheels.

The servos and dc motors are powered externally as arduino cannot supply enough power to them.

Figure-4.2: Complete Structure

4.2 ELECTRICAL IMPLEMENTATION

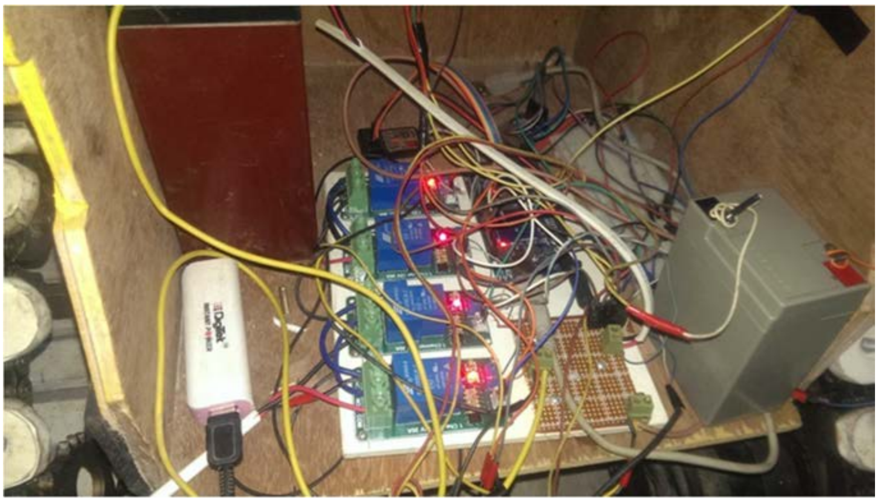

Figure-4.3: Implemented Circuit

4.3 SOFTWARE DESIGN

Arduino Code

```
#include <Servo.h>

#include <SD.h>

#define SD_ChipSelectPin 53  //example uses hardware SS pin 53 on Mega2560

//#define SD_ChipSelectPin 4

#include <TMRpcm.h>

#include <SPI.h>


Servo leftServo, rightServo, neckServo, eyeServo;

TMRpcm myAudio;
```

```
int ch1;
int ch2;
int ch3;
int ch4;
int ch5;
int ch6;
int x,y;

#define LR1  8   //Left Motor Drive
#define LR2  9
#define RR1 10  //Right Motor Drive
#define RR2 11
void setup() {

  pinMode(2, INPUT);
  pinMode(3, INPUT);
  pinMode(4, INPUT);
  pinMode(5, INPUT);
  pinMode(6, INPUT);
  pinMode(7, INPUT);
  digitalWrite(LR1,LOW);
  digitalWrite(LR2,LOW);
  digitalWrite(RR1,LOW);
```

```
digitalWrite(RR2,LOW);

pinMode(LR1,OUTPUT);
pinMode(LR2,OUTPUT);
pinMode(RR1,OUTPUT);
pinMode(RR2,OUTPUT);

leftServo.attach(A0);
rightServo.attach(A1);
neckServo.attach(A2);
eyeServo.attach(A3);

  myAudio.speakerPin = 46; //5,6,11 or 46 on Mega, 9 on Uno, Nano, etc
//Complimentary Output or Dual Speakers:
pinMode(45,OUTPUT); //Pin pairs: 9,10 Mega: 5-2,6-7,11-12,46-45

Serial.begin(115200);
//pinMode(13,OUTPUT); //LED Connected to analog pin 0
if (!SD.begin(SD_ChipSelectPin)) {  // see if the card is present and can be initialized:
  Serial.println("SD fail");
  return;   // don't do anything more if not
}
else{
  Serial.println("SD ok");
}
```

```
  myAudio.setVolume(7); //louder
  myAudio.quality(1);
  myAudio.play("1.wav");

  delay(4000);
}


void loop() {
  ch1 = pulseIn(2, HIGH); // Read the pulse width of
  ch2 = pulseIn(3, HIGH); // each channel
  ch3 = pulseIn(4, HIGH);
  ch4 = pulseIn(5, HIGH);
  ch5 = pulseIn(6, HIGH);
  ch6 = pulseIn(7, HIGH);

  // WHEEL CONTROL

  if(ch1 > 1050 && ch1 < 1300){
    turn_left();
  }
  else if(ch1 > 1700){
    turn_right();
  }
```

```
 else if(ch2 > 1700){
   go_forward();
 }
else if(ch2 > 1100 && ch2 < 1300){
   go_backward();
 }
else{
   motor_stop();
}

// eyeServo Control pin = A3

if(ch3 > 1800){
     x=eyeServo.read();
   for(int i=x; i<=80; i++){
     eyeServo.write(i);
     delay(10);
  }
   myAudio.play("1.wav");
   Serial.println("UP");
}
else if(ch3 > 1100 && ch3 < 1300){
   eyeServo.attach(A3);
   y = eyeServo.read();
```

```
    for (int k = y; k >= 40; k--){
      eyeServo.write(k);
      delay(10);
      Serial.println(eyeServo.read());
    }
    myAudio.play("1.wav");
    Serial.println("DOWN");
}
else{
    eyeServo.detach();
}

//neckServo Control A2

if(ch4 > 1050 && ch4  < 1200){    //A2
    neckServo.attach(A2);
    neckServo.write(80);
    delay(100);
    Serial.println("LEFT");
}
else if(ch4 > 1800){
    neckServo.attach(A2);
    neckServo.write(100);
    delay(100);
    Serial.println("RIGHT");
```

```
}
else{
   neckServo.detach();
}

if(ch5 > 1500){
   myAudio.play("3.wav");
   int rightServoPos = map(ch5,988,1990,60,180); //A1
   for(int m=100; m<180; m++){
    rightServo.write(m);
    delay(15);
}
    Serial.println(rightServo.read());
}

if(ch5 > 988 && ch5 < 1500){
    myAudio.play("3.wav");
    int rightServoPos = map(ch5,988,1990,60,180); //A1
    for(int n=180; n>100; n--){
     rightServo.write(n);
     delay(15);
   }
   //Serial.println(rightServo.read());
}
```

```
if(ch6 > 0){
   myAudio.play("3.wav");
    int leftServoPos = map(ch6,1130,1990,60,90); //A0
    leftServo.write(leftServoPos);
    delay(15);
 }
   delay(100);
}
void turn_left(){
   delay(50);
   digitalWrite(LR1,LOW);
   digitalWrite(LR2,LOW);
   digitalWrite(RR1,LOW);
   digitalWrite(RR2,HIGH);

   Serial.println("Turning Left");
}
void turn_right(){
   delay(50);
   digitalWrite(LR1,LOW);
   digitalWrite(LR2,HIGH);
   digitalWrite(RR1,LOW);
   digitalWrite(RR2,LOW);
```

```
  Serial.println("Turning Right");
}
void go_forward(){
   delay(50);
   digitalWrite(LR1,LOW);
   digitalWrite(LR2,HIGH);
   digitalWrite(RR1,LOW);
   digitalWrite(RR2,HIGH);
   Serial.println("Going Forward");
}
void go_backward(){
   delay(50);
   digitalWrite(LR1,HIGH);
   digitalWrite(LR2,LOW);
   digitalWrite(RR1,HIGH);
   digitalWrite(RR2,LOW);
   Serial.println("Going Backward");
}
void motor_stop(){
   digitalWrite(LR1,LOW);
   digitalWrite(LR2,LOW);
   digitalWrite(RR1,LOW);
   digitalWrite(RR2,LOW);
      Serial.println("Motor Stopped !");
}
```

Chapter-5

Experimental Result

5.1 DC Single Shaft Gear Motor

Operating Voltage: 12-24V

RPM: 60

5.2 Left Wheel

Starting Current: 15A

Average Current: 9A

5.3 Right Wheel

Starting Current: 10A

Average Current: 7A

5.4 Relay

Operating Voltage: 12V

5.5 Arduino

Current consumed per Pin: 40mA

Voltage Applied: 9V

5.6 Servo Motors for Hands

Voltage applied: 5V

Current: 2.20A

5.6 <u>Servo Motors for Eye</u>

Voltage applied: 5V

Current: 1.85A

5.6 <u>Servo Motors for Neck</u>

Voltage applied: 5V

Current: 1.57A

Chapter-6
Conclusion

6.1 LIMITATIONS

- For rotating the eye we intended to use micro servo motor (SG90) but the weight of the eye was beyond its capacity so had to use metal gear servo motor (MG995).
- The wheel was constructed previously with dual shaft dc motor but that imposed problems with the chain alignment, therefore we had to use single shaft dc motor (wiper motor of Toyota corolla).
- Starting current of relay for the wheel's dc gear motor was 13A so the 10A relay shield burnt and we had to use 30A relay shield.
- If we use 12 volt battery the wheel propels with hindrance, so 24V is used.

6.2 FINAL REMARK

This Electromechanical robot can mainly be used for entertainment purpose and can be controlled wirelessly.

6.3 FUTURE MODIFICATIONS

Future work will seek to improve this electromechanical robot by incorporating ultrasonic sensor and movement control through voice recognition and gesture.

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